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NEVADA ENGINEERING AND TECHNOLOGY CORP LONG BEACH CA  
FABRICATION OF FORGED CLOSE-IN WEAPON SYSTEM (CIWS) PENETRATORS--ETC(U)  
NOV 79 R G SHERMAN  
NETCO-0166F

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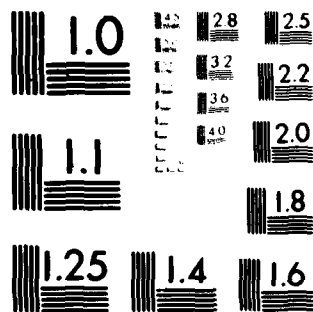
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) THIS PROGRAM EVALUATED THE FORGEABILITY U-2%MO CAST AND SOLUTION TREATED AND AGED BLANKS. AND ALSO EVALUATED WAS U-3/4T1 ALLOY EXTRUDED BAR IN THE AS EX- TRUDED CONDITION FROM BOTH RMI AND NMI AS WELL AS THE SOLUTION TREATED CONDITION. THE FORGING EVALUATION WAS DONE BY FORGING THE PHALANX PENETRATOR TO NET SHAPE. ALL MATERIALS WERE SUCCESSFULLY FORGED EVEN THOUGH THE HARDNESSES VARIED FROM Rc28 to Rc40.		

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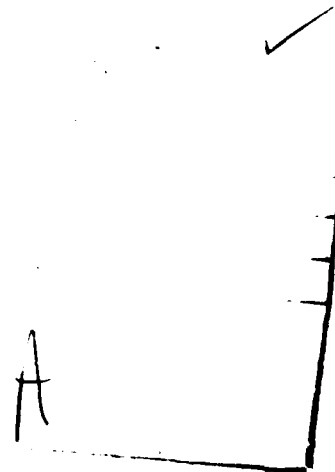
FINAL REPORT

TITLE:  
FABRICATION OF FORGED CLOSE-IN  
WEAPON SYSTEM (CIWS) PENETRATORS

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WHITE OAK  
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#### ABSTRACT

This program evaluated the forgeability U-2%Mo cast and solution treated and aged blanks. And also evaluated was U-3/4Ti alloy extruded bar in the as extruded condition from both RMI and NMI as well as the solution treated condition.

The forging evaluation was done by forging the Phalanx penetrator to net shape. All materials were successfully forged even though the hardnesses varied from Rc28 to Rc40.

## INTRODUCTION

The Phalanx penetrator is produced from DU-2%Mo alloy either extruded or hot rolled bar stock. Investment casting has been considered as a method of producing an oversize blank which can be machined to finish size. If casting of individual blanks can be cost effective then it follows that a cast blank required for net shape forging might be less expensive than one produced from rod.

The amount of DU-2%Mo alloy required for Phalanx production is small compared to the tonnage of U-.75Ti alloy needed for GAU-8 and XM774. Since there are only three U.S. producers of uranium alloy rod and they are all heavily committed to the U-.75% Ti alloy there may someday be a problem obtaining the DU-2%Mo alloy.

This program was aimed at determining what problems might be encountered from using either cast U-2%Mo blanks as a starting stock for net shape forging or using DU-.75%Ti alloy bar stock.

## TECHNICAL DISCUSSION

The parts fabricated on this contract were made to Print #8081015. The main difference between this print and Print #2923571 are listed below. These drawings are attached.

1. The configuration of the nose was changed to eliminate the small flat between the 45° cone and the tapered front.
2. The tolerances on the 1.526" and the 1.013" lengths were changed to  $\pm .010$ " instead of  $\pm .005$ ".
3. The surface finish requirement was changed to 63RMS from 32RMS.

All of these changes have the effect of reducing costs and we found it considerably easier to make the parts for this program using the new print.

The net shape forging process requires a relatively precise starting blank, .460" diameter X 1.455" long. The blank must be lubricated in order to prevent galling in the carbide dies. A molybdenum disulfide dry film lubricant was used for this program and no galling problems were encountered.

The blanks were induction heated using a temperature between 360°C and 525°C and forged in a  $\frac{1}{2}$ " National 4 station cold header. The die configuration produced a blank .470" diameter, with the 1.013" cylinder section to size, the .513" tapered front end to size and the

### TECHNICAL DISCUSSION(contd)

rear spinner slot to size. Following forging, the dry film lubricant was removed by mill polishing in a vibratory bowl.

Using a Monarch EE tracer lathe the front .100" diameter nose, 45° cone and the boat tail were machined. Very few difficulties were encountered in performing these operations. The most time consuming operation was the preparation of the blanks for forging. Listed below in Table 1 are the starting materials for this program.

TABLE I. MATERIALS EVALUATED FOR FORGING PHALANX PENETRATORS.

<u>NETCO #</u>	<u>SOURCE</u>	<u>HARDNESS</u>	<u>DESCRIPTION</u>
N6*	Nuclear Metals	Rc 29/30	DU-2%Mo Cast blanks from melt #5 Solution treated and aged .525" diameter by 1.5" cylinder section
N7	Nuclear Metals	Rc 28/29	As above except melt #6
N8	RMI	Rc 30/38	DU-.75%Ti-as extruded GAU-8 bar stock .600/.690" dia.
N4	Nuclear Metals	Rc 26/28	DU-.75%Ti as extruded GAU-8 blanks .690" diameter
N3	Nuclear Metals	Rc 38/42	As above except blanks were solution treated.

\* WE USED DIFFERENT PUNCHES FOR EACH GROUP SO THAT ALL PARTS ARE PERMANENTLY IDENTIFIED IN THE SPINNER SLOT.

We attempted to obtain hot rolled GAU-8 material as produced by NL Albany, but both that company and Honeywell refused to sell us this material. Although Item 0001AB of the contract requires only 25 DU-3/4Ti forged penetrators we believed that a comparison of RMI alpha extruded and NMI gamma and solution treated material might prove beneficial. We believe that Navy would have been better served if hot rolled DU-3/4Ti had been included.

We kept the identity of melt lots #5 and #6 because the ballistic properties of penetrators from melts 1,2,3, and 4 from a previous NMI contract varied. In this work by NMI, Melt #1 was a virgin heat of DU-2%Mo, Melts #2,3 and 4 included an increasing amount of recycled chips and showed a progressive increase in carbon content. We believed that there might be a difference in ballistic properties of penetrators from #5 and #6. Although we have no knowledge of the history of these two heats it is our understanding that #5 is a virgin heat and #6 is a remelt. This would make #5 and #6 equivalent to #1 and #2 of the previous contract.

Machining the forging blank from the casting blank was somewhat difficult because the blank was too short to turn the diameter over the entire 1.455" length in one set up. This required turning the partially turned blank and chucking from the other end. As a result of this, many of the blanks have a slight line in the cylinder section. This slight mismatch caused no problems in forging and there are a number of finished parts with a built in surface "defect" for stress corrosion evaluation.

The cast blanks forged well and we did not notice any difference between these and extruded blanks. The DU-3/4Ti blanks also forged to net shape. However the forging characteristics of the three types were distinctly different which could not be explained on the basis of Rockwell hardness. The mechanical properties of these three types might vary and this in turn may cause differences in ballistic properties.

During the forging evaluation we attempted to produce the entire front end to net shape with only the .100" diameter point oversize in length. We were able to forge several parts to this configuration but the .100" diameter knockout pin was too small to sustain the stresses developed and broke each time. Figure 1 is a photograph of the starting blank, the net shape forging and the finish machined part. After a number of attempts the die developed a chip and we discontinued this development work. The only major difference in processing we encountered was in the turning operation. The turning chip on the solution treated material did not break off but instead hung on and was troublesome during machining. This material seemed to have excellent ductility and toughness and might have excellent ballistic properties.

During the course of this investigation there were discussions by the Navy as to the surface finish requirements for the Phalanx penetrator. One comment relayed to NETCO was that no ballistic evaluation or stress corrosion tests had ever been made on penetrators with a surface finish of RMS 63 or greater. We therefore prepared a number of blanks with different surface finish characteristics. Because we processed more than the 25 penetrators required for each of the three items of the contract, we sent to Dahlgren many extra blanks incorporating the variations. Some of the parts have a finish of 160RMS. Listed below in Table II are the quantities of each group shipped.

TABLE II. QUANTITY AND TYPES OF MATERIAL OF FORGED PHALANX PENETRATORS.

<u>LOT #</u>	<u>ITEM #</u>	<u>QUANTITY</u>	<u>COMMENTS</u>
N3	0001AB	18	Solution treated DU-3/4Ti RMS 30/40
N4	0001AB	20	As extruded NMI DU-3/4Ti RMS 40/50
N8	0001AB	20	As extruded RMI DU-3/4Ti 15 parts RMS 40/60 5 parts RMS 100/180
N6	0001AA	16	Castings #5 RMS 30/50
N7	0001AA	35	Castings #6 RMS 20/40



We had several forged blanks of each of these categories which we have filed away for future reference. These should be used as part of a larger program listed in the recommendations section.

### SUMMARY

We carried out a program which evaluated cast and solution treated and aged blanks as a starting material for forging the DU-2%Mo alloy Phalanx penetrator.

Also evaluated was the DU-3/4Ti alloy as produced by RMI and NMI. The NMI material was evaluated in both the as extruded and the solution treated condition while the RMI material was evaluated in the as extruded material. Despite relatively large differences in hardness, Rc 28 to Rc 40, all material could be forged to net shape.

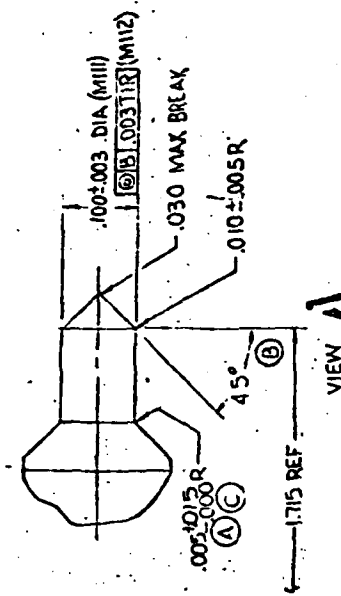
### CONCLUSIONS

1. DU-2%Mo cast blanks, solution treated and aged can be net shape forged to the Phalanx penetrator configuration.
2. DU-3/4Ti as extruded by RMI and NMI differ significantly in hardness but both can be net shape forged to the Phalanx penetrator configuration.
3. DU-3/4Ti solution treated to Rc 38/40 can be net shape forged to the Phalanx penetrator configuration.

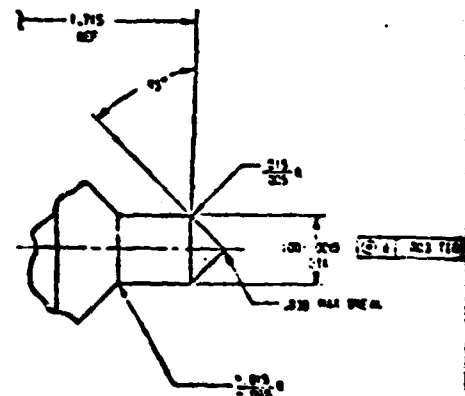
### RECOMMENDATIONS

The mechanical properties such as tensile and impact properties of all materials which have been fabricated into Phalanx penetrators should be determined. These properties should be correlated with the ballistic properties. These data would help to finalize the specification covering the Phalanx penetrator.

If the DU-3/4Ti alloy becomes an acceptable alternate to the DU-2Mo alloy, work should be carried out aimed at reducing costs. The extrusion size for starting stock either for forging or machining will be considerably smaller than the size evaluated by the contract. This may result in different metallurgical and mechanical properties and therefore forging and machining characteristics as well as ballistic properties may vary.



**DRAWING #8081015**



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BY	A. J. C.
<b>APPLICATIONS</b>	





Figure 1. Photograph of the Starting Blank, the Net Shape Forging and the Finish Machined Part.

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